ARTopos - Augmented Reality Terrain Map Visualization for Collaborative Route Planning

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Abstract
Most outdoor activities, such as alpine climbing, cycling, or hiking, require a careful route planning in advance. Today, most routing applications are single-user desktop applications. Furthermore, it is good practice to be able to do paper map based navigation during the trip as a backup. In this work, we propose ARTopos, a concept and implementation of a augmented reality (AR) 3D topographic map visualization, which combines analog paper map planning and digital routing service. It augments paper topographic maps with a digital terrain map suitable for interaction and displaying forecast information. We implemented a first prototype for which we gathered generally positive qualitative feedback as a first initial evaluation. We envision ARTopos as an interactive, collaborative tool can be used during the preliminary trip briefing for most adventurous activities.

Author Keywords
collaborative routing; tour planning; augmented reality, topographic maps; map visualization

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

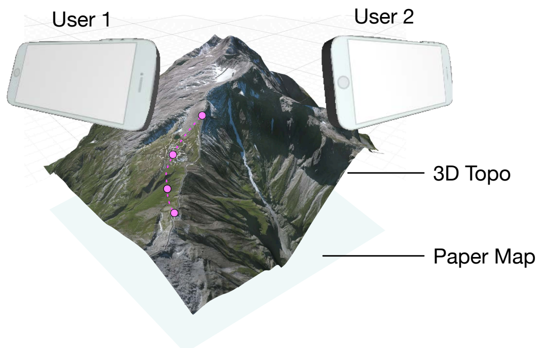

Figure 1: System Overview

Introduction

Most kinds of outdoor activities have in common that they require a route to be planned before. For example when hiking in the mountains, the length and elevation profile usually determines the total trip duration, which is constraint by time between sunrise and sunset. It will also have an effect of the choice of gear and nutrition that will be brought to the trip. Mistakes and inaccuracies during this process might have severe consequences. This is why the planning for these types of activities is more time consuming and typically reassured in a mandatory preliminary briefing, at which all members of the team are present.

In addition to the more static parameters such as length and the elevation profile of the route, dynamically changing conditions have to considered as well. This includes, e.g., weather, the difficulty of the terrain, or warnings from local institutions. For more remote tours, the source of geographic information would need to be cross verified or must come from a trusted publisher. As gathering an parsing all this information, discussing it and finally decide for a specific route is a highly interactive process, we argue that the use augmented reality can be beneficially in this process.

Related Work

Hedley et al. explored two types of hybrid interfaces for collaborative geographic data visualization including the use of AR on paper based maps with pen based annotations [1]. A similar approach for AR map based interaction with more focus on pattern recognition and maker based AR manipulations tools was carried out by Bobrich & Otto [2]. The authors stress the natural interaction between the user and the system for moving, rotating and the change of perspective. Wang integrated planning rules into an construction worksite AR planner in order to prevent mistakes during the the process of planning in to increase overall productivity [5].

Piper et al. proposed a computational analysis of landscape models with a 3D tangible user interface (TUI) for landscape analysis. The authors found their their TUI to convey naturally and clearly convey spatial relationships and to be intuitive, since it is directly manipulated by the user's hands [3].

ARTopos Concept

ARTopos is a tabletop augmented reality application which uses a paper topographic map as marker. It is based on the idea that all team members either in reality or virtually (using some kind of telepresence) sit around a table for the a preliminary trip planning meeting. For interacting with the digital world, every user can take his or her personal smartphone. Figure 1 shows an overview over the system components involved.

Paper Topographic Map as AR Marker
The paper topographic map is folded out on the table. This naturally synchronizes the orientation and the scale of the map across devices. Only the digital interaction has therefore to be synched over network, such as the finger tabs. Using a paper map as the AR has the the following conceptual reasons:

- The paper map acts as a cross verification of the digital terrain map. This eases the process of map alignment as the orientation of the analog and the digital map correspond to each other [4].
- The analog paper map can be annotated manually with a pencil during the interaction with the digital map, including, e.g., weather information. The paper map can be taken to the trip as a backup for navigation and thought the processes it is assured that the state of both maps are synchronous. The paper map backup is especially important as one would not usually only rely on GPS and digital maps. As taking such a backup is already common practice, this process should play well with the existing workflow for route planning.
- The print and the paper quality of a professionally made topographic maps will most of the time be be the preferred option over self-printed maps. For this reason and also because the process of the manual annotation itself might have an advantage in terms of acquired spatial knowledge during the planning phase of the trip already. This could decrease the need for navigational aids during the trip.

Map Interactions
We argue that AR as a visualization technique plays is suited for our route planning scenario as it supports the following natural map interactions:

Figure 2: The ARTopos prototype in use in the mountains.

- *Zooming*: Once the user physically comes closer to the paper map, the digital map get zoomed in.
- Through the use of digital map, remote collaboration becomes possible. Often, teams for adventurous activities are put together from qualified specialists at remote locations. When a remote participant possesses the same paper map as a maker, the application can be used to, e.g., mark locations over network.

However, we think that not only the geographic result of the route planning is important but also the common understanding that is established in preliminary discussion for which we envision ARTopos as an interactive tool. Using it during the briefing will assure that everyone in the team is on the same page.

Implementation

Figure 2 shows the prototype we implemented for ARTopos. It is based on the Mapbox Unity SDK[1], Unity, and the Vuforia AR Toolkit[2]. The 3D terrain model used for augmentation is a realistic representation of the world and comes with its corresponding WGS84 spatial reference system. Therefore, a single tab on the screen, which is projected to the 3D model using a simple ray-casting algorithm, can be converted into latitude and longitude coordinates. The anchor points of a single route can be created by different users. Once the points have been defined, a directions REST API is queried with the respective routing profile (e.g. walking or cycling).

The route is rendered as a 3D mesh. As the height information is missing in the response from the directions API, we project the the points of the individual route legs to the terrain maps, similar as we do with the touch interactions. It may be that the changes in height than it does in direction. Hence, we interpolate between to points of the original route to achieve a smother adaptation of the 3D route mesh to the terrain.

Conclusion

We proposed a concept for AR collaborative route planning and a concept for a combination for combining paper map and digital map based interactions. A first prototype has been created that realized AR as video-see-through with smartphones and enabled uses to collaboratively define a multi-destination route. With our current prototype we gathered first qualitative feedback from 6 participants who overall found the approach promising. One participant stated that the 3D visualization was very helpful for planning the elevation profile of multiple-day backpacking trips. In preparation for a in-depth user study, we plan to add other AR techniques than video-see-through, e.g. the Microsoft Hololens. We think that AR has the advantage that it enables hands-free interaction with the map. Thus, it would be possible to combine manual and paper based annotation and interaction with the digital terrain model.

[1] https://www.mapbox.com/unity-sdk/
[2] https://www.vuforia.com/

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